Need of Improved Non-Destructive Technique for the Surface Condition Monitoring of High Speed Steel (HSS) Work Rolls

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ABSTRACT

Over the last few years, the use of work rolls for hot rolling of flat steel has changed from clear chill rolls to indefinite chill, then came high chrome steel and now High Speed tool Steel (HSS). The hardness of HSS roll reaches 80/85 ShC, hence it becomes very much crack-sensitive and the developed crack is usually oriented parallel to the roll axis and propagates in a non-radial direction. In the next phase, a fatigue "cat's tongue" like fracture band propagates progressively in a circumferential direction running more or less parallel to the barrel surface. The direction of propagation is opposite to that of the direction of roll rotation. Crack propagation develops within the working surface of the roll, gradually increasing in depth and width followed by a large surface spall of the overlying barrel surface. Hence it is highly recommended to eliminate all kinds of surface cracks, whenever these rolls are reground, otherwise these `cats - tongue' band type spalls may lead to abnormal failure. This paper presents the necessity of development of improved non-destructive technique for the crack detection of HSS rolls and also highlights the recent attempts at Tata Steel in collaboration with CSIR-National Metallurgical Laboratory, Jamshedpur to develop surface wave based ultrasonic technique to detect fine cracks on the barrel surface of HSS rolls to optimise the grinding procedure for having crack free roll surface.

Introduction

Work rolls are subjected to high stress during hot rolling of heavy plates in the hot strip mills. High surface pressure combined with cyclic thermal stress leads to micro structural changes within the material. Moreover surface flaws are formed in work rolls used for rolling under abnormal rolling conditions. These surface flaws can expand to large cracks when repeatedly subjected to high stress and thereby causing problems like roll spalling and that may cause emergency shutdown of roll mill due to the breakup of rolls. According to statistics, 95% roll breakups result from surface and subsurface flaws [1]. To cope with the wear and surface roughening of the work rolls, the rolling process is interrupted at regular intervals to grind off and to recondition the roll surface. After each grinding, roll surface is examined by surface flaw detector. Usually eddy current and dye penetrant techniques are being used for checking of surface conditions of the work rolls.

Over the last few years the use of work rolls for hot rolling of flat steel has changed. In the roughing stands, conventional high chrome steel (70 - 75 ShC) has been gradually replaced by new grades like carbide enhanced high chrome steel (75 - 80 ShC), ultra low carbon grades like Semi - HSS, matrix type HSS (80 - 90 ShC), Konkordia (Cr-based HSS) and the variety of other HSS grades (HSS 75 - 85 ShC). Due to roll size and production demands placed on the rougher rolls, these developments follow mainly the first finishing stands F1-F4 to increase the campaign times and for better surface finish. The HSS rolls have high hardness and good wear resistance at high temperatures and excellent surface roughening resistance. This type of roll is used in finishing applications of a hot strip mill for increased campaign times and better surface finish. They were found to perform better than the conventional centrifugally cast high cast iron rolls. During rolling process of the rolls, micro-cracks often initiate in and proceed along hard carbides distributed in the microstructure [2,3]. HSS rolls can be fractured unexpectedly by spalling or thermal fatigue caused by the growth of internal cracks or by the roughening of the roll surface. Hence it is highly recommended to eliminate all kinds of surface cracks, whenever these rolls are reground otherwise typical `cats'-tongue band type spalls may occur. Surface crack depth determination by ultrasonic surface wave has been reported by Hetchmann Paul et al. and Takada Hazime et al. [4, 5] have been reported earlier.

At Tata Steel, though a regular eddy current and ultrasonic testing are performed after each grinding and before placing the rolls back to the stands, still few rolls failure had taken place in the last few months. Figure 1 shows a typical crack network and spall that has occurred in one of the work rolls at Tata Steel.

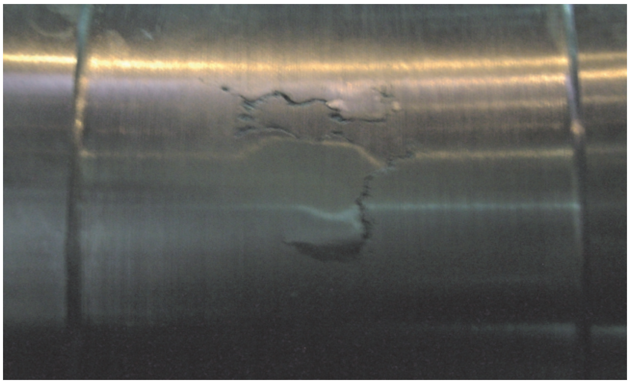

Fig. 1: Crack networks and spall occurred on the roll surface

This paper describes the application of 0.5 MHz ultrasonic surface wave to detect fine cracks on the barrel surface of HSS rolls as well as to optimise the grinding procedure for having crack free roll surface.

Measurements on Rolls:

Figure 2 shows the schematic of the setup used for the measurements. Measurements were carried out along the length of the roll in the working area at an interval of 100 mm in both clock and anti-clock wise directions by rotating the probe to cover the entire circumference. Hence the scanning was carried out in the axial direction whereas wave was propagating in the circumferential direction. Ultrasonic flaw detector (Einstein II, make Modsonic) and 0.5 MHz surface wave probe (make Krautkramer) was used for the study. The Gain of the flaw detector was fixed to 87 dB throughout all measurements.

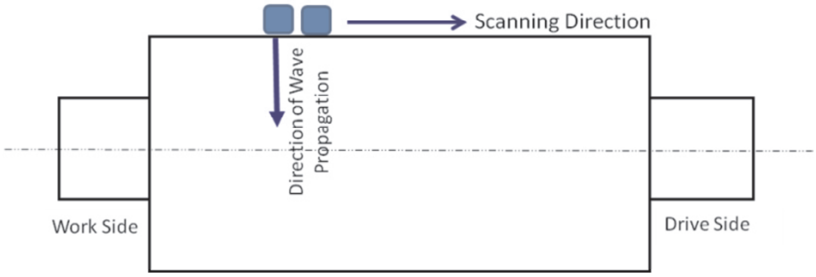

Fig. 2: Schematic of the measurement setup on the roll

Measurements were carried out on

1. finishing mill dirty roll #2302 of diameter 683 mm and length 1700 mm
2. finishing mill finished roll #2301 of diameter 683 mm and length 1700 mm
3. finishing mill cracked roll # 2344 of diameter 700 mm and length 2000 mm

Results

Measurements on finishing mill dirty roll #2302 and finishing mill finished roll #2301

Measurements were carried out on each roll at 12 positions at a distance of 100 mm in both, clock and anti-clock wise directions. The signals observed at one such location in the clockwise and anti-clockwise directions of roll #2302 and #2301 are shown in figure 3 below:

The amplitudes of the reflected echoes from half the circumference at different locations of the two rolls of finishing mill is plotted and is shown in figure 4. The plot shows that the amplitude of the reflected echo from half the circumference in the finished roll is quite high compared to that of the dirty roll. With the reduction in surface roughness, the signal amplitude increases and the signal amplitude is nearly same in all the measured locations. It shows there is no such surface anomaly in the measured roll.

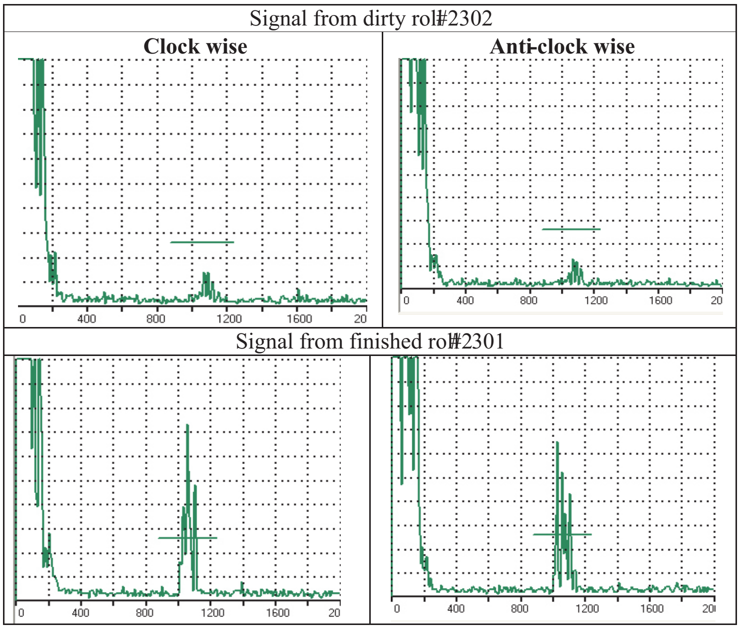

Fig. 3: Ultrasonic back wall echo from a distance of 1090 mm observed at one location of dirty roll #2302and finished roll #2301 of finishing mill

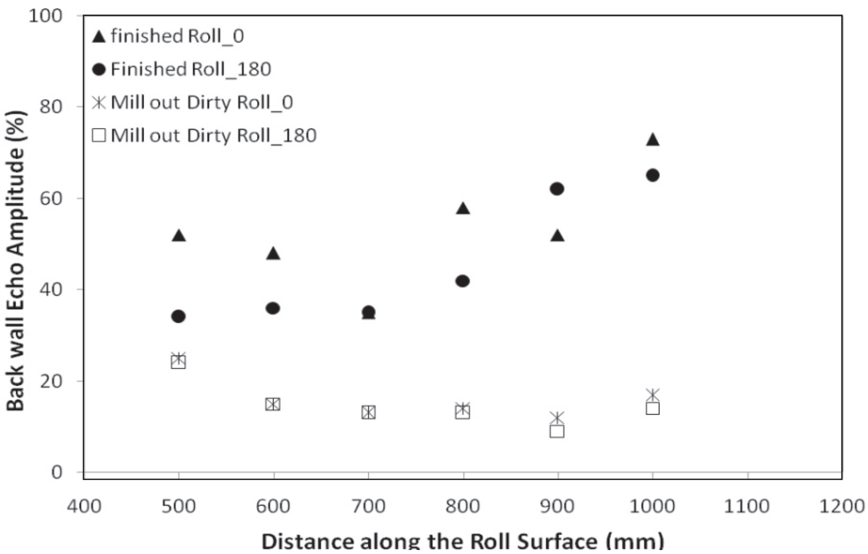

Fig. 4: Amplitudes of the reflected echo from half the circumference at different measured locations of the rough and finished roll of the finishing mill

Measurements on finishing mill cracked roll #2344

Measurements were carried out on HSS roll #2344 of length 2000 mm and diameter 700 mm that has cracked after first campaign and the crack depth was 5.96 mm (approx). Scanning was carried out along the length of the roll in both clock and anti-clockwise directions and total scan time was 5 mins. Crack echo was observed from a position of 1150 mm and ends at 1450 mm along the length from the work side of the Roll. All measurements were carried out by placing the probe at a fixed distance in the radial direction from the crack position. Eddy current testing was also used to detect the crack extension on the surface of the roll and was found 230 mm whereas by surface wave ultrasonic it was 300 mm. The maximum crack echo amplitude was observed at a distance of 1280 mm from the work side of the roll. The roll was then grinded off step wise and after each step ultrasonic measurement was carried out till the crack echo amplitude become zero. Figure 5 shows the signals corresponding to the various crack depths.

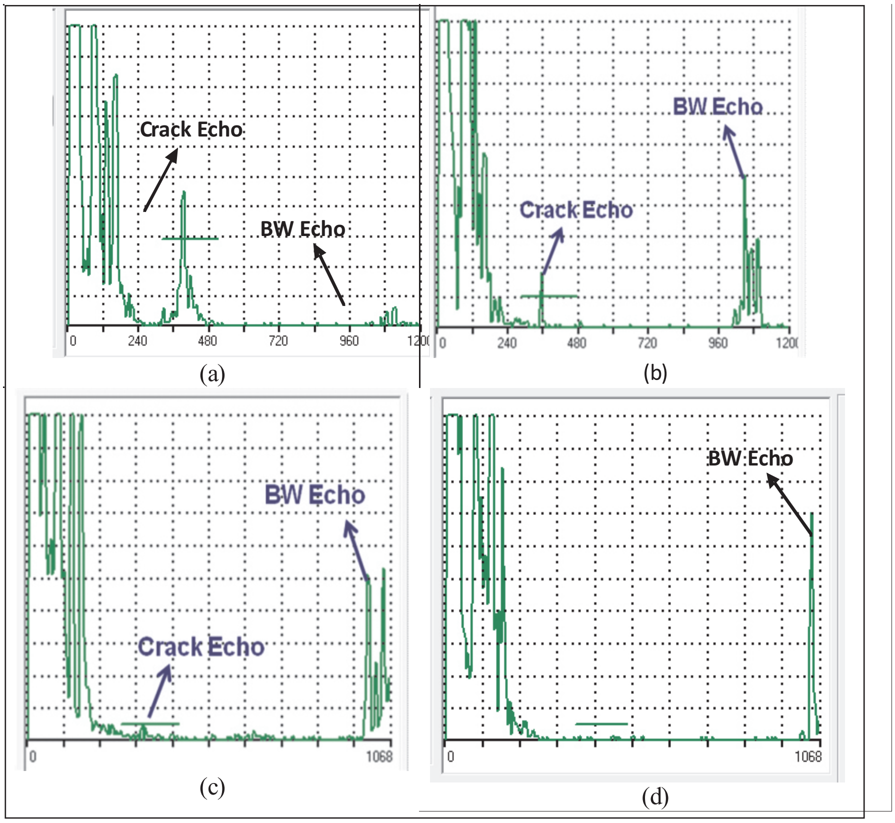

Fig. 5: Ultrasonic signals at 1280 mm from the work side with crack depths of (a) 5.965 mm, (b) 1.465mm, (c) 0.43 mm and (d) no crack

Calibration curve has been made for HSS roll using the back-wall echo amplitude with the crack depth. Table 1 below depicts the crack depth and corresponding back wall echo amplitude.

Table 1: Crack depth Vs. Back wall Echo Amplitude

Crack depth (mm)	Back wall echo amplitude (%)
0	70
0.435	53
1.465	50
5.965	0.75

Figure 6 below shows the variation of back wall echo amplitude with crack depth from a fixed distance with fixed gain.

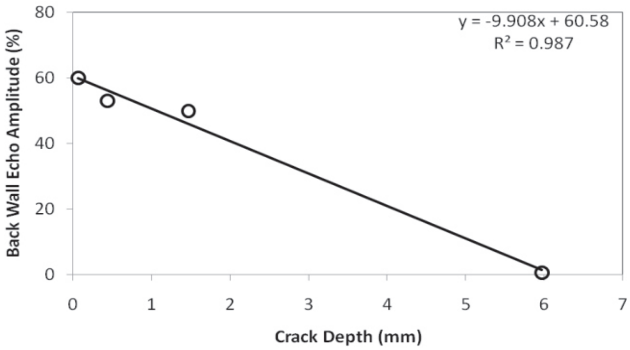

Fig.e 6: Back wall echo amplitude vs. crack depth measured from a fixed distance with fixed Gain

Conclusion

- This work establishes the application of 0.5 MHz surface wave probe for the surface condition detection of High Speed tool Steel (HSS) rolls.
- Calibration for back wall echo amplitude with crack depth for fixed gain fixed distance has been established for HSS roll.
- From the calibration curve, and the back wall echo amplitude, optimal grinding condition can be estimated that will reduce the rate of roll failure at HSM.

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